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Panama Canal, official handbook

Ancon, Canal Zone

1913

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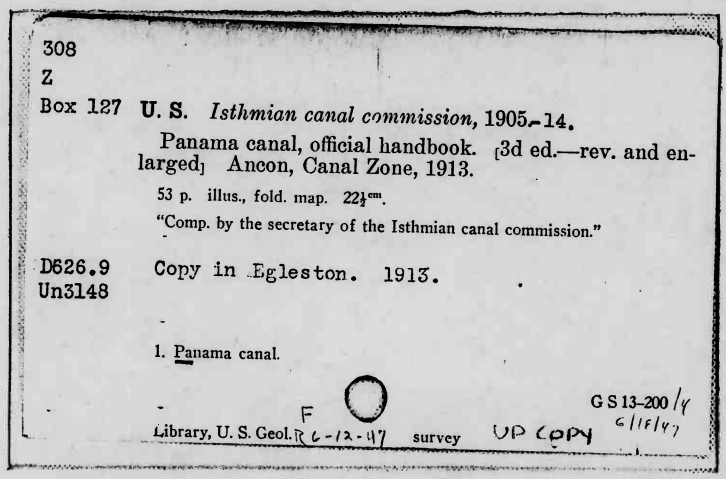

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The Panama Canal

THIRD EDITION—REVISED AND ENLARGED

COMPILED BY
THE SECRETARY OF THE ISTHMIAN CANAL COMMISSION

Ancon, Canal Zone
1913

Panama Canal

Official Handbook

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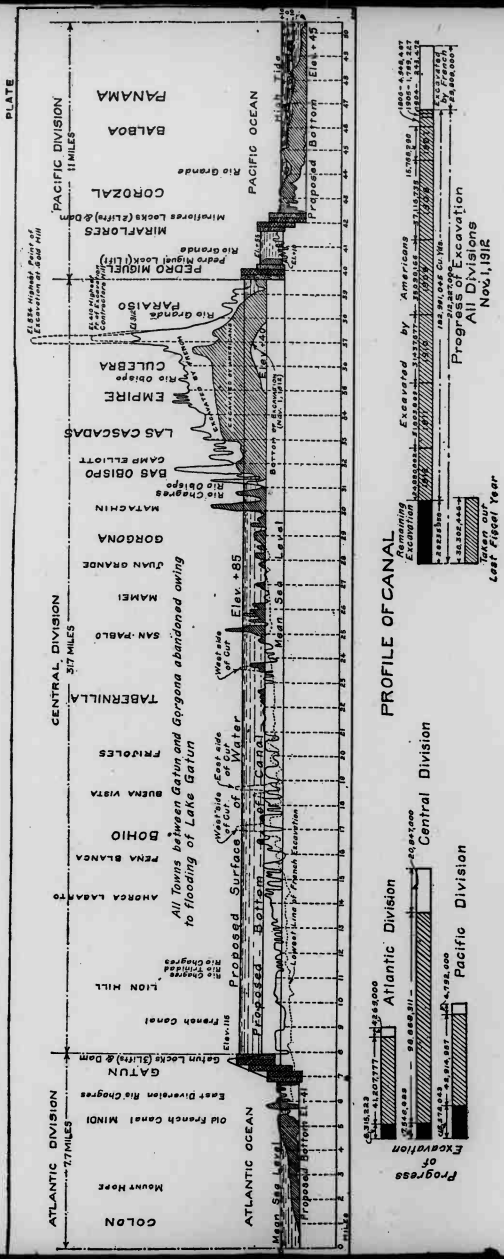

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Locks, usable length (feet)	1,000
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Gatun Lake, area (square miles)	164
Gatun Lake, channel depth (feet)	85 to 45
Culebra Cut, channel depth (feet)	45
Excavation, Canal Proper, estimated total (cubic yards)	203,710,000
Excavation, Permanent Structures, estimated (cubic yards)	8,794,000
Excavation, grand total, estimated (cubic yards)	212,504,000
Excavation, Due to Slides and Breaks, estimated (cubic yards) about	22,000,000
Excavation accomplished January 1, 1913, (cubic yards)	188,280,312
Excavation, Remaining, Canal Proper, January 1, 1913, (cubic yards)	23,426,713
Excavation by the French (cubic yards)	78,146,960
Excavation by French, useful to present Canal, (cubic yards)	29,908,000
Excavation by French, estimated value to Canal	$25,389,240
Value of all French property	$42,799,826
Concrete, total estimated for Canal (cubic yards)	5,000,000
Time of transit through completed Canal (hours)	10 to 12
Time of passage through locks (hours)	3
Relocated Panama Railroad, total cost	$8,866,392.02
Relocated Panama Railroad, length (miles)	47.11
Canal Zone, area (square miles)	436
Canal and Panama Railroad force actually at work (about)	36,000
Canal and Panama Railroad force, Americans (about)	5,000
Cost of Canal, estimated total	$375,000,000
Work begun by Americans	May 4, 1904
Date of official opening	Jan. 1. 1915

THE Panama Canal does not, as is quite generally thought, cross the Isthmus from east to west. As is shown on the accompanying map, its general direction is from northwest to southeast, the Pacific entrance near Panama being about 22½ miles east of the Atlantic entrance near Colon. It is a lake canal as well as a lock canal, its dominating feature being Gatun Lake, a great body of water covering about 164 square miles and occupying the northern half of that portion of the Isthmus through which the Canal passes. This lake is an elevated body of water with a surface level maintained at from 85 to 87 feet above sea level by the Gatun Dam and locks on the Atlantic side and the Pedro Miguel Locks and Dam on the Pacific side. (Plate B.) The Culebra Cut is really an arm of the lake. On both Atlantic and Pacific sides there is an approach channel, which is an inlet of the sea, extending from deep water in the sea up to the foot of the locks which lift vessels to the level of the lake through which they are to pass.

The entire length of the Canal from deep water in the Atlantic to deep water in the Pacific is about 50 miles. Its length from shore-line to shore-line is about 40 miles. In passing through it from the Atlantic to the Pacific, a vessel will enter the approach channel in Limon Bay, which has a bottom width of 500 feet and extends to Gatun, a distance of about 7 miles. At Gatun it will enter a series of three locks in flight and be lifted 85 feet to the level of Gatun Lake. It may steam at full speed through this lake, in a channel varying from 1,000 to 500 feet in width, for a distance of about 24 miles, to Bas Obispo, where it will enter the Culebra Cut. It will pass through the Cut, a distance of about 9 miles, in a channel with a bottom width of 300 feet, to Pedro Miguel. There it will enter a lock and be lowered 30⅓ feet to a small lake, at an elevation of 54⅔ feet above sealevel, and will pass through this for about 1½ miles to Miraflores. There it will enter two locks in series and be lowered to sealevel, passing out into the Pacific through a channel about 8½ miles in length, with a bottom width of 500 feet. The depth of the approach channel on the Atlantic side, where the maximum tidal oscillation is 2½ feet, will be 41 feet at mean

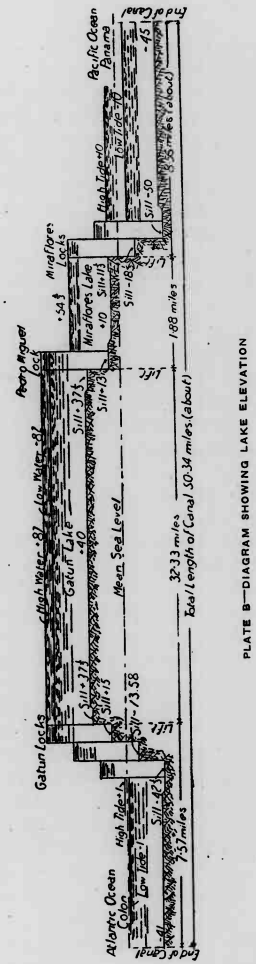


PLATE 8—DIAGRAM SHOWING LAKE ELEVATION

tide, and on the Pacific side, where the maximum oscillation is 21 feet, the depth will be 45 feet at mean tide. The mean sealevel in both oceans is the same.

Throughout the first 15 miles from Gatun, the width of the Lake channel will be 1,000 feet; then for 4 miles it will be 800 feet, and for 4 miles more, to the northern entrance of Culebra Cut at Bas Obispo, it will be 500 feet. The depth will vary from 85 to 45 feet. The water level in the Cut will be that of the Lake, the depth 45 feet.

Three hundred feet is the minimum bottom width of the Canal. This width begins about half a mile above Pedro Miguel locks and extends about 8 miles through Culebra Cut, with the exception that at all angles the channel is widened sufficiently to allow a thousand-foot vessel to make the turn. The Cut has eight angles, or about one to every mile. The 300-foot widths are only on tangents between the turning basins at the angles. The smallest of these angles is 7° 36′, and the largest 30°.

In the whole Canal there are 22 angles, the total curvature being 600° 51′. Of this curvature, 281° 10′ are measured to the right, going south, and 319° 41′ to the left. The sharpest curve occurs at Tabernilla, and is 67° 10′.

GATUN DAM

The Gatun Dam, which forms Gatun Lake by impounding the waters of the Chagres and its tributaries, is nearly 1½ miles long, measured on its crest, nearly ½ mile wide at its base, about 400 feet wide at the water surface, about 100 feet wide at the top, and its crest will be finished at an elevation of 105 feet above mean sea level, or 20 feet above the normal level of the Lake. It is in reality a low ridge uniting the high hills on either side of the lower end of the Chagres Valley so as to convert the valley into a huge reservoir. Of the total length of the Dam only 500 feet, or one-fifteenth, will be exposed to the maximum water head of 85 to 87 feet. The interior of the Dam is formed of a natural mixture of sand and clay, dredged by hydraulic process from pits above and below the Dam, and placed between two large masses of rock

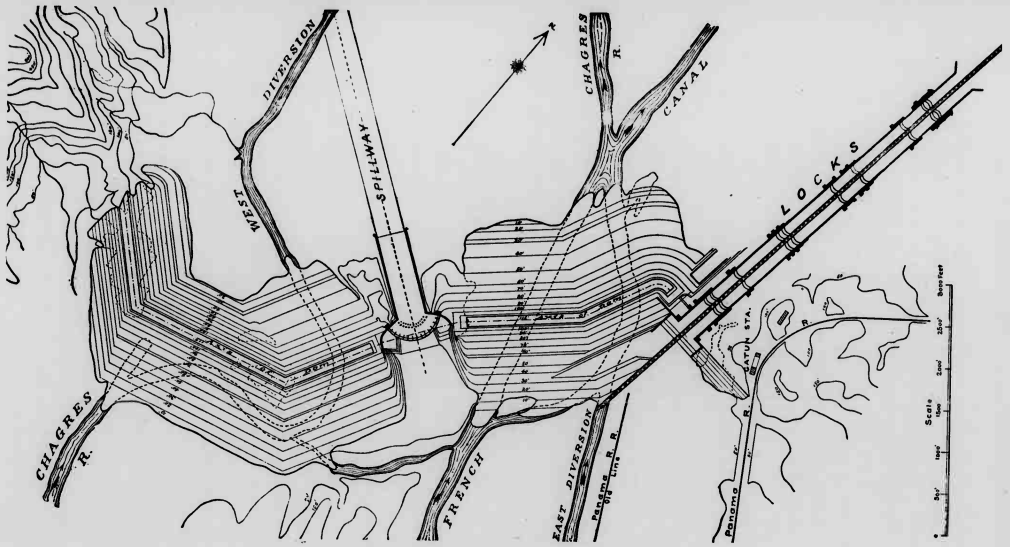


PLATE C—GATUN DAM; SPILLWAY AND LOCKS

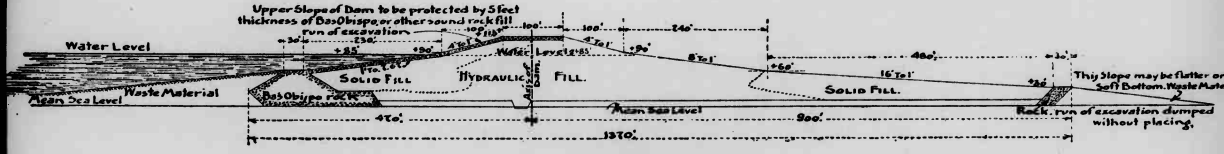

Upper Slope of Dam to be protected by 5 feet thickness of Bas Obispo or other sound rock fill
Run of excavation
Water Level
Waste Material
Gatun Sea Level
Solid Fill
Hydraulic Fill
Bas Obispo Rock
Solid Fill
This Slope may be flatter on Soft Bottom. Waste Materia
Rock, run of excavation dumped without placing.
1370'
900'

PLATE D—CROSS SECTION GATUN DAM

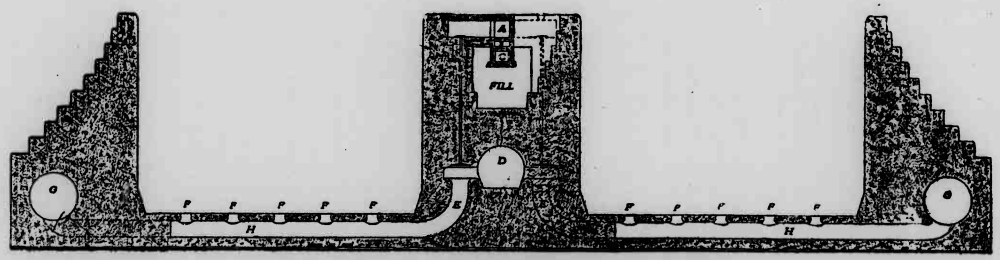


PLATE E—CROSS SECTION OF LOCK CHAMBERS AND WALLS OF LOCKS

A—Passageway for operators.
B—Gallery for electric wires.
C—Drainage gallery.
D—Culvert in center walls
E—These culverts run under the lock floor and alternate with those from side walls.
F—Wells opening from lateral culverts into lock chamber.
G—Culverts in sidewalls.
H—Lateral culverts.

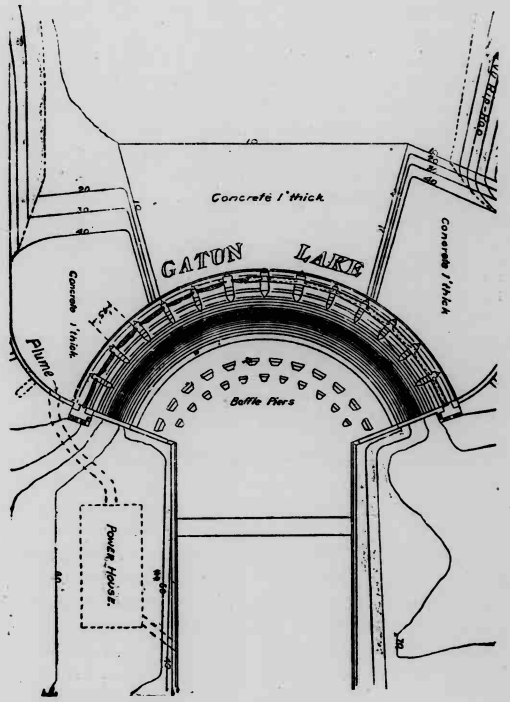
and miscellaneous material obtained from steam shovel excavation at various points along the Canal. The top and upstream slope will be thoroughly riprapped. The entire Dam will contain about 21,000,000 cubic yards of material. (Plates C and D.)

SPILLWAY, GATUN DAM

The Spillway is a concrete lined channel 1,200 feet long and 285 feet wide cut through a hill of rock nearly in the center of the Dam, the bottom being 10 feet above sealevel at the upstream end and sloping to sealevel at the toe. Across the upstream or lake opening of this channel a concrete dam has been built in the form of an arc of a circle making its length 808 feet although it closes a channel with a width of only 285 feet. The crest of the dam will be 69 feet above sea level, or 16 feet below the normal level of the lake which is 85 feet above sea level. On the top of this dam there will be 13 concrete piers with their tops 115.5 feet above sealevel, and between these there will be mounted regulating gates of the Stoney type. Each gate will be of steel sheathing on a framework of girders and will move up and down on roller trains in niches in the piers. They will be equipped with sealing devices to make them water-tight. Machines for moving the gates are designed to raise or lower them in approximately ten minutes. The highest level to which it is intended to allow the lake to rise is 87 feet above sealevel, and it is probable that this level will be maintained continously during wet seasons. With the lake at that elevation, the regulation gates will permit of a discharge of water greater than the maximum known discharge of the Chagres River during a flood. (Plate F.)

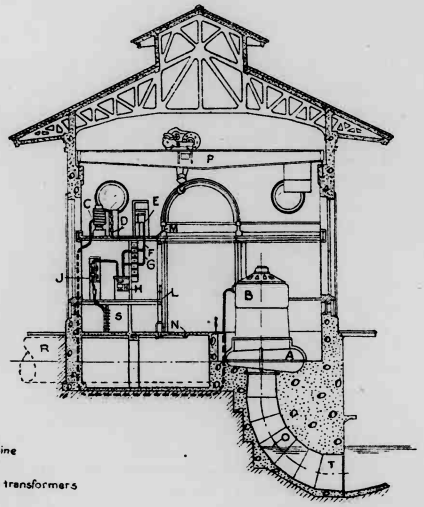
HYDROELECTRIC STATION AT GATUN

Adjacent to the north wall of the spillway will be located a hydroelectric station capable of generating through turbines 6,000 kilowatts for the operation of the lock machinery, machine shops, dry dock, coal-



Courtesy of "The Panama Guide"

PLATE F—SPILLWAY OF GATUN DAM



A - 2,250 k. w. water turbine
B - 2,000 k. w. generator
C - Reactance
D - Generator instrument transformers
E - Generator switches
F - Bus 1
G - Bus 2.
H - Circuit switches
J - Circuit instrument transformers
L - First gallery (el. + 40.85)
M - Second gallery (el. + 55.35)
N - Main floor (el. + 33.25)
O - Low water (el. + 7)
P - 30 ton crane.
R - Penstock.
S - Cable Vault.
T - Draft Tube.

PLATE G—HYDROELECTRIC STATION

handling plant, batteries, and for the lighting of the locks and Zone towns and, if desirable, the Panama railroad. The building will be constructed of concrete and steel, and will be of a design suitable for a permanent power house in a tropical country. The dimensions will be such as to permit the installation of three 2,000-kilowatt units, and provision will be made for a future extension of three additional similar units. It will be rectangular in shape, and will contain one main operating floor, with a turbine pit and two galleries for electrical equipment. The building, with the machinery and electrical equipment, will be laid out upon the unit principle, each unit consisting of an individual head gate, penstock, governor, exciter, oil-switch, and control panel.

Water is to be taken from Gatun Lake, the elevation of which will vary with the seasons from 80 to 87 feet above sealevel, through a forebay which will be constructed as an integral part of the curved portion of the north spillway approach wall. From the forebay the water will be carried to the turbines through three steel plate penstocks, each having an average length of 350 feet. The entrances will be closed by cast iron headgates and bar iron trash racks. The headgates will be raised and lowered by individual motors which will be geared to rising stems attached to the gate castings. The driving machinery and the motors will be housed in a small concrete gatehouse erected upon the forebay wall directly over the gate recesses and trash racks. The gatehouse will be constructed for the present requirements of three headgates, and provision will be made for a future addition of three more units. (Plate G.)

WATER SUPPLY OF GATUN LAKE

Gatun Lake will impound the waters of a basin comprising 1,320 square miles. (*See Map.*) When the surface of the water is at 85 feet above sealevel, the lake will have an area of about 164 square miles, and will contain about 183 billion cubic feet of water. During eight or nine months of the year, the lake will be kept constantly full by the prevailing rains, and con-

sequently a surplus will need to be stored for only three or four months of the dry season. The smallest run-off of water in the basin during the past 22 years, as measured at Gatun, was that of the fiscal year, 1912, which was about 132 billion cubic feet. Previous to that year the smallest run-off of record was 146 billion cubic feet. In 1910 the run-off was 360 billion cubic feet, or a sufficient quantity to fill the lake one and a half times. The low record of 1912 is of interest as showing the effect which a similar dry season, occuring after the opening of the Canal, would have upon its capacity for navigation. Assuming that the Gatun Lake was at elevation plus 87 at the beginning of the dry season on December 1st, and that the hydroelectric plant at the Gatun Spillway was in continuous operation, and that 48 lockages a day were being made, the elevation of the lake would be reduced to its lowest point, plus 79.5, on May 7th, at the close of the dry season, after which it would continuously rise. With the water at plus 79 in Gatun Lake there would be 39 feet of water in Culebra Cut, which would be ample for navigation. The water surface of the lake will be maintained during the rainy season at 87 feet above sea level, making the minimum channel depth in the Canal 47 feet. As navigation can be carried on with about 39 feet of water, there will be stored for the dry season surplus over 7 feet of water. Making due allowance for evaporation, seepage, leakage at the gates, and power consumption, this would be ample for 41 passages daily through the locks, using them at full length, or about 58 lockages a day when partial length is used, as would be usually the case, and when cross filling from one lock to the other through the central wall is employed. This would be a larger number of lockages than would be possible in a single day. The average number of lockages through the Sault Ste. Marie Canal on the American side was 39 per day in the season of navigation of 1910, which was about eight months long. The average number of ships passed was about 1½ per lockage. The freight carried was about 26,000,000 tons. The Suez Canal passed about 12 vessels per day, with a total tonnage for the same year of 16,582,000.

The water level of Gatun Lake, extending through the Culebra Cut, will be maintained at the south end by an earth dam connecting the locks at Pedro Miguel with the high ground to the westward, about 1,400 feet long, with its crest at an elevation of 105 feet above mean tide. A concrete core wall, containing about 700 cubic yards, will connect the locks with the hills to the eastward; this core wall will rest directly on the rock surface and is designed to prevent percolation through the earth, the surface of which is above the Lake level.

A small lake between the locks at Pedro Miguel and Miraflores will be formed by dams connecting the walls of Miraflores locks with the high ground on either side. The dam to the westward will be of earth, about 2,700 feet long, having its crest about 15 feet above the water in Miraflores Lake. The east dam will be of concrete, containing about 75,000 cubic yards; will be about 500 feet long, and will form a spillway for Miraflores Lake, with crest gates similar to those at the Spillway of the Gatun Dam.

THE LOCKS

There will be 6 double locks in the Canal; three pairs in flight at Gatun, with a combined lift of 85 feet; one pair at Pedro Miguel, with a lift of 30⅓ feet, and two pairs at Miraflores, with a combined lift of 54⅔ feet at mean tide. The usable dimensions of all are the same—a length of 1,000 feet, and width of 110 feet. Each lock will be a chamber, with walls and floor of concrete, and mitering gates at each end.

The side walls will be 45 to 50 feet wide at the surface of the floor; will be perpendicular on the face, and will narrow from a point 24⅓ feet above the floor until they are 8 feet wide at the top. The middle wall will be 60 feet wide, approximately 81 feet high, and each face will be vertical. At a point 42⅓ feet above the surface of the floor, and 15 feet above the top of the middle culvert, this wall will divide into two parts, leaving a space down the center much like the letter "U," which will be 19 feet wide at the bottom and 44 feet wide at the top. In this center space will be a tunnel divided into three stories, or galleries. The

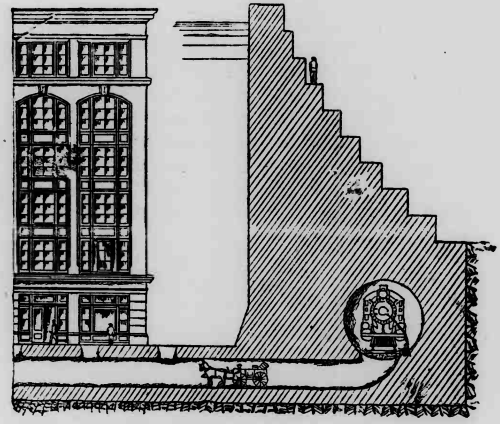


PLATE H—SIDE WALL OF LOCKS COMPARED WITH SIX-STORY BUILDING

lowest gallery will be for drainage; the middle, for the wires that will carry the electric current to operate the gate and valve machinery installed in the center wall, and the upper will be a passageway for the operators. (Plate E.)

The lock gates will be steel structures seven feet thick, 65 feet long, and from 47 to 82 feet high. They will weigh from 390 to 730 tons each. Ninety-two leaves will be required for the entire Canal, the total weighing 60,000 tons. The leaves are shells of structural steel covered with a sheathing of steel riveted to the girder framework. Each leaf is divided horizontally into two separate compartments. The lower compartment is watertight, for the purpose of making the leaf so buoyant that it will practically float in the water and thus largely relieve the stress upon the bearings by which it is hinged to the wall. This watertight compartment is subdivided vertically into three sections, each independently watertight so that if the shell should be broken in any way or begin to leak, only one section would probably be affected. An air shaft 26 inches in diameter runs from the bottom compartment up to the top of the gate, and this also is watertight where it passes through the upper half of the leaf.

Intermediate gates will be used in all except one pair of the locks, in order to save water and time; if desired, in locking small vessels through, the gates being so placed as to divide the locks into chambers 600 and 400 feet long, respectively. Ninety-five per cent of the vessels navigating the high seas are less than 600 feet long.

The highest gates and the highest lock walls on the Canal are those of the lower locks at Miraflores, and these locks are the only ones which have no intermediate gates. The total lift from mean sea level to the level of Miraflores Lake, $54\frac{2}{3}$ feet, is equally divided between the upper and lower locks, and under ordinary conditions, all should be of equal volume. The waters of the Pacific, however, extend into the lower locks, and the range of tide is from 10 feet below to 10 feet above mean sea level. Furthermore, the area of the upper locks is greater than the lower because of the omission of the intermediate gates in the latter.

The combined result is that the volume of each lower lock is less than that of the upper when the tide is higher than about two feet below mean tide, and the lock is incapable of receiving the full contents of an entire upper lock without causing an overflow of the walls and gates. A portion of the water from an upper lock must be wasted through the culverts or cross-emptied into the twin lock. To diminish this waste as much as practicable, the volume of the lower locks has been enlarged by increasing the height of the walls and gates to 82 feet which is the maximum consistent with economy and safety in construction.

In the construction of the locks, it is estimated that there will be used approximately 4,200,000 cubic yards of concrete, requiring about the same number of barrels of cement.

The locks will be filled and emptied through a system of culverts. One culvert 254 sq. ft. in area of cross section, about the area of the Hudson River tunnels of the Pennsylvania railroad, (Plate H.) extends the entire length of each of the middle and side walls and from each of the large culverts, there are several smaller culverts 33 to 44 sq. ft. in area, which extend under the floor of the lock and communicate with the lock chamber through holes in the floor. The large culverts are controlled at points near the miter gates by large valves and each of the small culverts extending from the middle wall feeds in both directions through laterals, thus permitting the passage of water from one twin lock to another, effecting a saving of water. (Plate E.)

To fill a lock the valves at the upper end are opened and the lower valves closed. The water flows from the upper pool through the large culverts into the small lateral culverts and thence through the holes in the floor into the lock chamber. To empty a lock the valves at the upper end are closed and those at the lower end are opened and the water flows into the lower lock or pool in a similar manner. This system distributes the water as evenly as possible over the entire horizontal area of the lock and reduces the disturbance in the chamber when it is being filled or emptied. (See also "Electric Control of Lock Machinery" p. 26.)

The depth of water over the miter sills of the locks will be 40 feet in salt water and 41½ feet in fresh water.

The average time in filling and emptying a lock will be about fifteen minutes, without opening the valves so suddenly as to create disturbing currents in the locks or approaches. The time required to pass a vessel through all the locks is estimated at 3 hours; one hour and a half in the three locks at Gatun, and about the same time in the three locks on the Pacific side. The time of passage of a vessel through the entire Canal is estimated as ranging from 10 to 12 hours, according to the size of the ship, and the rate of speed at which it can travel.

GATE-MOVING MACHINERY

The machinery for opening and closing the miter gates was invented in the office of the Assistant Chief Engineer by Edward Schildhauer, Electrical and Mechanical Engineer, and a patent has been issued on it. It is the subject of the illustration herewith. (Plate I.) It consists essentially of a crank gear, to which is fastened one end of a strut or connecting rod, the other end of which is fastened to a lock gate. The wheel moved through an arc of 197 degrees, closes or opens the gate leaf, according to the direction in which it is turned. One operation takes 2 minutes. The crank gear is a combination of gear and crank, is constructed of cast steel, is 19 feet 2 inches in diameter, and weighs approximately 35,000 pounds. It is mounted in a horizontal position on the lock wall; turns on a large center pin, and is supported at the rim in four places by rollers. The center pin is keyed into a heavy casting anchored securely to the concrete. The crank-gear has gear teeth on its rim and is driven through a train of gears and pinions by an electric motor in a contiguous room. The motor is remotely controlled by an operator who is stationed at a center control house near the lower end of the upper locks. A simple pull of a small switch is sufficient to either close or open a 700-ton gate, the operation being perfectly automatic.

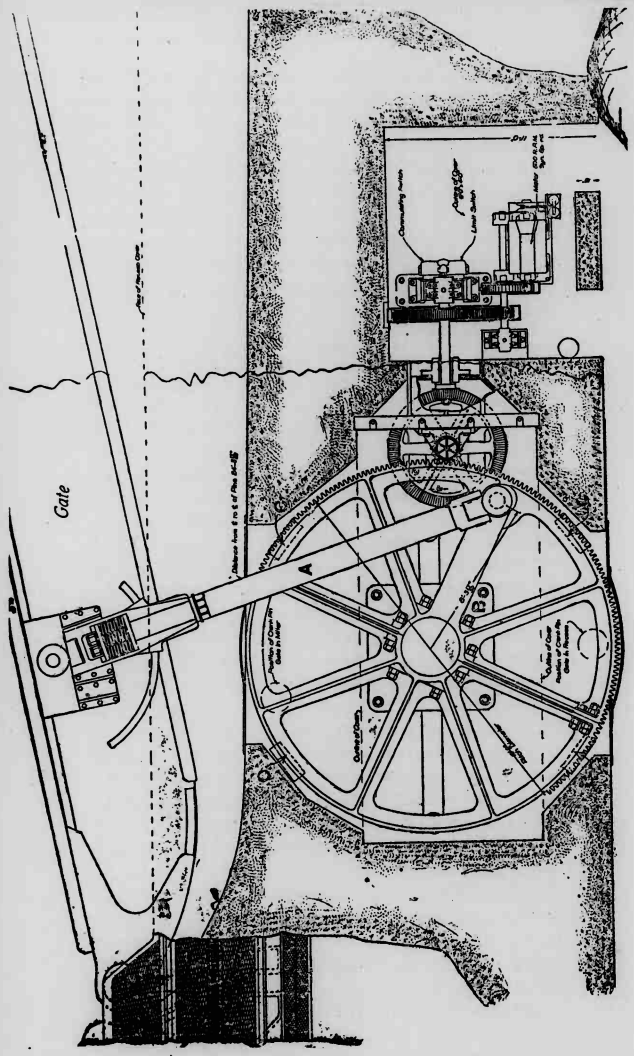


PLATE I—LOCK GATE OPERATING MACHINE SHOWING RELATION OF BULL WHEEL TO STRUT AND GATE

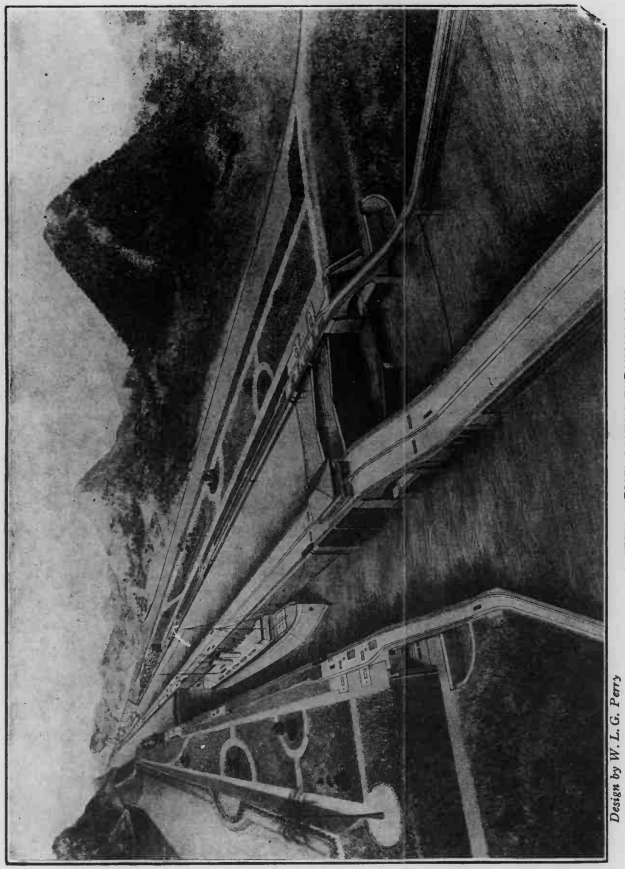
(A) Strut or Connecting Rod. (B) Bed Plate. (C) Bearing Wheel.

No ship will be allowed to pass through the locks under its own power, but will be towed through by electric locomotives operating on tracks on the lock walls. The system of towing provides for the passing through the locks of a ship at the rate of 2 miles an hour. The number of locomotives will vary with the size of the vessel. The usual number required will be 4: 2 ahead, 1 on each wall, imparting motion to the vessel, and 2 astern, 1 on each wall, to aid in keeping the vessel in a central position and to bring it to rest when entirely within the lock chamber. (Plates J and K.) They will be equipped with a slip drum, towing windlass and hawser which will permit the towing line to be taken in or paid out without actual motion of the locomotive on the track. The locomotives will run on a level except when in passing from one lock to another they climb heavy grades. There will be two systems of tracks, one for towing, and the other for the return of the locomotives when not towing. The towing tracks will have center racks or cogs throughout, and the locomotives will always operate on this rack when towing. At the incline between locks the return tracks will also have rack rails, but elsewhere the locomotives will run by friction. The only crossovers between the towing and return tracks will be at each end of the locks, and there will be no switches in the rack rail.

PROTECTIVE DEVICES

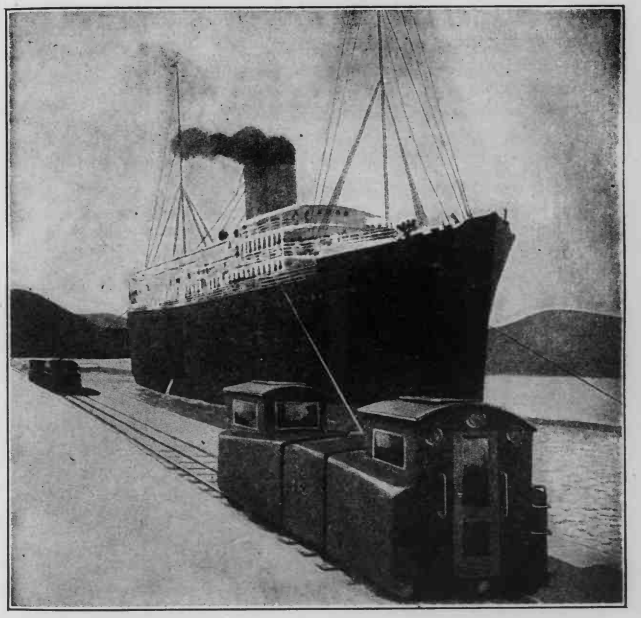
Several protective devices have been adopted to safeguard the gates in the locks.

First. Fender chains, 24 in number, each weighing 24,098 pounds, will be placed on the up-stream side of the guard gates, intermediate and safety gates of the upper locks, and in front of the guard gates at the lower end of each flight of locks. They will prevent the lock gates from being rammed by a ship that may approach the gates under its own steam or by escaping from the towing locomotives. In operation, the chain will be stretched across the lock chamber from the top of the opposing walls, and when it is desired to allow a ship to pass, the chain will be lowered into a groove made for



Design by W. L. G. Perry

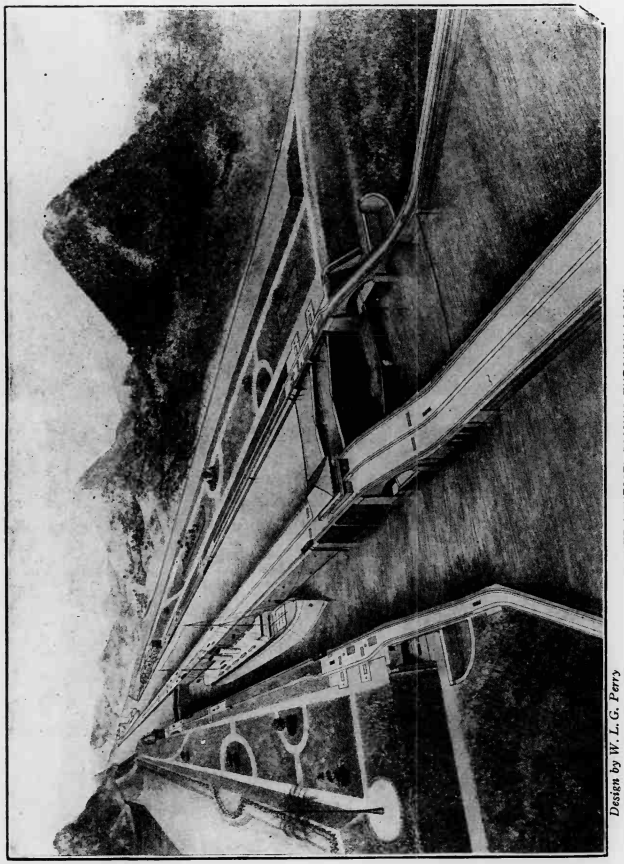
PLATE J—VESSEL PASSING THROUGH LOCKS



Courtesy of "Popular Mechanics"

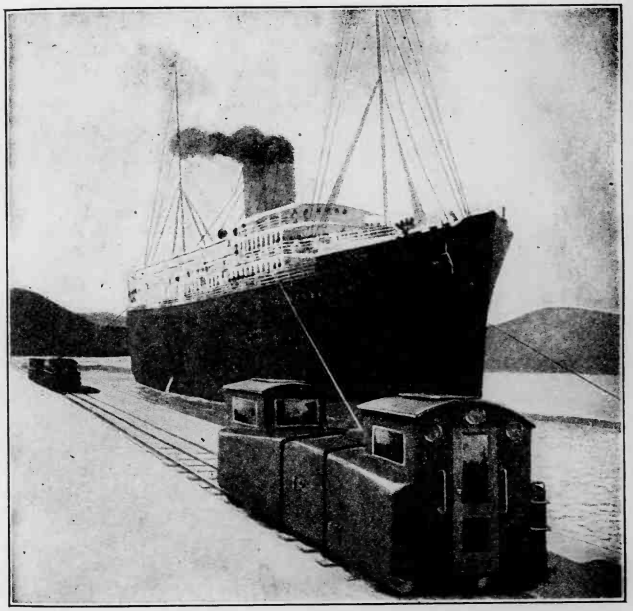
PLATE K—TOWING LOCOMOTIVES

INTENTIONAL SECOND EXPOSURE



Design by W. L. G. Perry

PLATE J—VESSEL PASSING THROUGH LOCKS



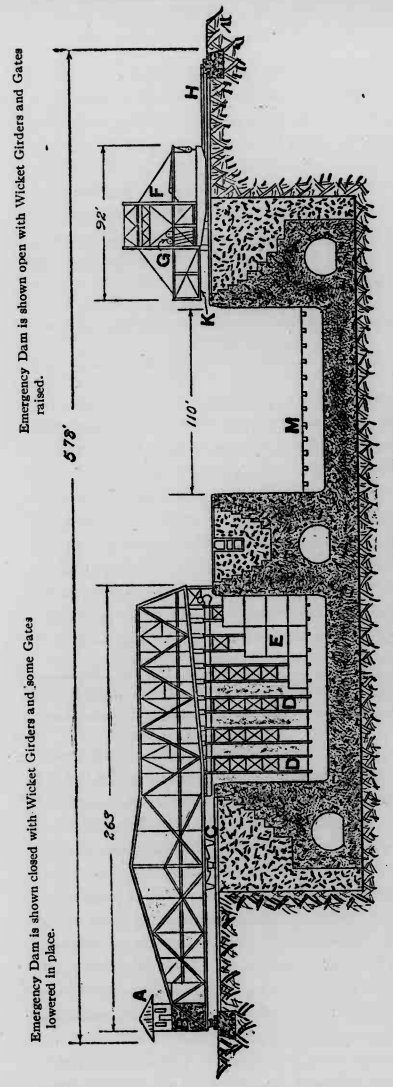
Courtesy of "Popular Mechanics'

PLATE K—TOWING LOCOMOTIVES

the purpose in the lock floor. It will be raised again after the ship passes. The raising and lowering will be accomplished from both sides by mechanism mounted in chambers or pits in the lock walls. This mechanism will consist of a hydraulically operated system of cylinders, so that 1 foot of movement by the cylinder will accomplish 4 feet by the chain. If a ship exerting a pressure of more than 750 pounds to the square inch should run into the fender, the chain will be paid out gradually by an automatic release until the vessel comes to a stop. Thus, a 10,000-ton ship, running at 4 knots an hour, after striking the fender can be brought to a stop within 73 feet, which is less than the distance which will separate the chain from the gate.

Second. Double gates will be provided at the entrances to all the locks and at the lower end of the upper lock in each flight, the guard gate of each pair protecting the lower gate from ramming by a ship which might possibly get away from the towing locomotives and break through the fender chain.

Third. A dam of the movable type called an emergency dam (Plate L) will be placed in the head bay above the upper locks of each flight for the purpose of checking the flow of water through the locks in case of damage, or in case it should be necessary to make repairs, or to do any work in the locks which would necessitate the shutting off of all water from the lake levels. Each dam will be constructed on a steel truss bridge of the cantilever type, pivoted on the side wall of the lock approach, and when not in use resting on the side wall parallel to the channel. When the dam is used the bridge will be swung across the channel with its end resting on the center wall of the lock. A series of wicket girders hinged to this bridge will then be lowered into the channel with their ends resting in iron pockets embedded in the lock floor. After the girders have been lowered into place, they will afford runways for gates which can be let down one at a time closing the spaces between the wicket girders. These gates will form a horizontal tier spanning the width of the Canal and damming the water to a height of 10 feet. Another series of panels will then be lowered, and so on until the dam, con-



(26)

structed from the bottom upward,completely closes the channel. When the dam has checked the main flow, the remainder, due to the clearance between the vertical sides of the gates, may be checked by driving steel pipes between the sides of the adjacent panels. These dams will be operated in three movements, and the machinery for operating is, therefore, in three classes, gate-moving, raising and lowering the wicket girders, and hoisting the gates on the girders, all driven by electric motors.

CAISSON GATES

To permit examining, cleaning, painting, and repairing the lower guard gates of the locks, and the Stoney gates of the Spillway dam, and for access in the dry to the sills of the emergency dams, it is proposed to provide floating caisson gates of the molded ship type. When their use is required the caissons will be towed into position in the forebay of the upper lock, above the emergency dam, or between the piers of the Spillway, and sunk. The caissons will be equipped with electric motor driven pumps for use in pumping out the caissons and for unwatering the locks.

ELECTRIC CONTROL OF LOCK MACHINERY

The gates, valves, and fender chains of the locks will be operated by electricity, and remotely controlled from a central point; that is, there will be a central control station for each of the series of locks at Gatun, Pedro Miguel, and Miraflores. In passing a ship through the locks it will be necessary to open and close the miter gates weighing from 390 to 730 tons, to fill and empty lock chambers containing from three and one half to five million cubic feet of water, to raise and lower fender chains weighing 24,098 pounds each, and to tow the vessel through the locks. All these operations, except that of towing, will be controlled by one man at a switchboard.

The control system for Gatun Locks is typical. Water is let into the lock chambers or withdrawn from

them by means of culverts under the lock floors, which connect with larger culverts in the lock walls, through which water is carried from the higher to the lower levels. The main supply culverts are 18 feet in diameter, and the flow of water through them is controlled by rising-stem gate valves, which can be completely opened or closed in one minute. In the center wall the culvert feeds both lock chambers, and therefore at each outlet into the lateral culverts there is a valve of the cylindrical type, in order that water may be let into or withdrawn from either chamber at will. A complete opening or closing of these cylindrical valves takes ten seconds. The miter gates are never opened or closed with a head of water on either side of them, the chambers being first emptied or filled by means of the valve and culvert system. The time required either to open or close the miter gate is two minutes.

A ship to be raised to the lake level will come to a full stop in the forebay of the lower lock, prepared to be towed through one of the duplicate locks by electric towing locomotives. The water in the lower lock chamber will be equalized with the sea level channel, after which the miter gates will be opened, the fender chain lowered and the vessel passed into the first chamber, where the water is at sea level. Then the miter gates will be closed. The rising stem gate valves at the outlet of the main culverts will be closed, while those above will be opened, allowing water to flow from an upper level into the lower chamber, which, when filled, will raise the vessel 28½ feet, to the second level. This operation will be repeated in the middle and upper locks until the ship has been raised to the full height of 85 feet above the level of the sea. At Gatun in the passing of a large ship through the locks, it will be necessary to lower 4 fender chains, operate 6 pairs of miter gates and force them to miter, open and close 8 pairs of rising stem gate valves for the main supply culverts, and 30 cylindrical valves. In all, no less than 98 motors will be set in motion twice during each lockage of a single ship, and this number may be increased to 143, dependent upon the previous condition of the gates, valves and other devices.

Each gate leaf, valve, and fender chain is operated by a separate motor mounted near the machinery in chambers in the lock wall, the motors acting through suitable gears (or pump in the fender chain) upon the various machines. In each machinery chamber will be erected a starting panel containing contactors by which current will be applied to the motor and these panels will in turn be controlled from a main unit in the central control house. Some of the machinery chambers at Gatun will be 2,700 feet distant from the point of control; 90 per cent of them will be within 2,000 feet, and 50 per cent of the total within 1,200 feet.

The station from which control will be exercised over the movement of all the machines will be on the center wall at the lower end of the upper flight of locks at Gatun, and similarly placed at Pedro Miguel and Miraflores. It will be in a building raised high enough above the top of the wall to allow a towing locomotive to pass under, a height of 16 feet, and to command an uninterrupted view of every part of the locks. In this house will be a double control board duplicated to conform to the duplication in locks. The control board will be in the nature of a bench or table, 32 inches above the floor, containing a representation, part model and part diagrammatic, of the flight of locks controlled by the respective series of switches. Standing at his switchboard the operator will throw the switches, and will see before him in model or diagram the progress of the fender chains as they rise and fall, the movement of the miter gates inch by inch, the opening and closing of the gate valves in the main culverts at every stage, the operation of the cylindrical valves, and, in addition, indication of the gradual rise or fall of the water in the lock chambers. The switches controlling the various motors, together with their indicators, will be mounted upon the board in the same relative position as the machines themselves in the lock walls. Some distortion of scale will be allowed, to give room for the switches. The board must not be over 4 feet in width, in order that the operator may be able to reach beyond the middle of it, and the length of the board is limited to 30 feet at Gatun, and proportionally at the other locks.

The system will be interlocking, so that certain motors can not be started in a certain direction until other motors are operated in a proper manner to obtain consistent operation on the whole, and to avoid any undesirable or dangerous combinations in the positions of valves, gates, or fender chains. In this way and by the use of limit switches the factor of the personal equation in operating the machines is reduced to a minimum, almost mechanical accuracy being obtained. Before the operating pair of valves in the main culverts can be opened, at least one pair of valves at the other ends of the locks, both upstream and downstream, must first be closed. This limits an operator to the act of equalizing water levels between locks, and keeps him from allowing water to flow from, say the lake level to the middle lock past the upper lock, thus preventing a possible flooding of the lock walls and machinery rooms. Interlocks, devoted to the control of action between the gate valves in the main culverts and the miter gates, prevent valves being opened a lock length above or below a miter gate which is being opened or closed, and thus prevent an operator causing a flow of water while the miter gates are being moved. Interlocks for the cylindrical valves guarding the openings from the center wall culvert to the lateral culverts will keep those of one side or the other closed at all times, except when it may be desired to cross-fill the chambers, when they may be opened by special procedure. An interlock prevents the operator from starting to open a miter gate before unlocking the miter-forcing machine. The miter gates guarded by a fender chain must be opened before the chain can be lowered, and the chain must be raised again before the gate can be closed, or more exactly the switches must be thrown in this order, but the operations may proceed at the same time. The simple interlocks will prevent such a mistake as leaving the chain down through lapse of memory when it should be up to protect the gate.

The general scheme of lighting and buoying the Canal contemplates the use of range lights to establish direction on the longer tangents and of side lights spaced about 1 mile apart to mark each side of the channel. The range lights are omitted in Culebra Cut, where their use is hardly practicable, and on four of the shorter tangents on the remainder of the Canal. In the Cut there will be placed three beacons at each angle, and between these intermediate beacons in pairs on each side of the Canal. By keeping his ship pointed midway between these beacons, the pilot will be able to adhere closely to the centre of the Canal. At each tangent it is necessary to have two ranges of two lights each to prolong the sailing line in order that the pilot may hold his course up to the point of turning. These range lights will be situated on land. There will be three types constructed, as shown by the cuts herewith, all of reinforced concrete (Plate M). The more elaborate structures will be used on the Gatun locks and dam and in the Atlantic and Pacific Divisions, where they are closer to the sailing lines of the vessels, while simpler structures will be placed in the Gatun Lake, where they are under less close observation. A light and fog signal on the west breakwater in Limon Bay is also included, (Plate P) and a light on the east breakwater, should it be built. The illuminants will be gas and electricity, the latter being used whenever the light is sufficiently accessible. For the floating buoys, and for the towers and beacons which are in inaccessible places, the system using compressed acetylene dissolved in acetone has been adopted. The buoys will be composed of a cylindrical floating body or tank, surmounted by a steel frame which supports the lens at a height of about 15 feet above the water level. The buoys will be moored in position along the edge of the dredged channel by a heavy chain and a concrete sinker, and should remain lighted for six to twelve months without being recharged. The candlepower of the range lights will vary, according to the length of the range, from about 2,500 to 15,000 candlepower. The most powerful lights will be those marking the sea channels at the Atlantic and Pacific entrances, they being visible from about 12 to 18 nautical miles. The beacons and gas-buoy lights

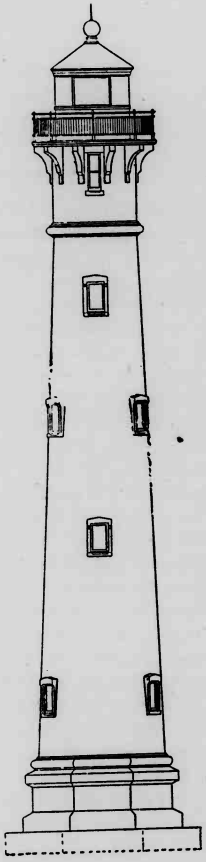


FIG. 1—ATLANTIC AND PACIFIC SECTIONS

FIG. 3—BEACON FOR CULEBRA CUT

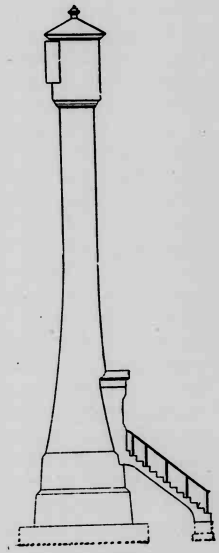


FIG. 2—GATUN LAKE

PLATE M—RANGE LIGHT TOWERS AND BEACONS

will have about 850 candlepower. White lights will be used throughout, and, in order to eliminate the possibility of confusing the lights with one another and with the lights on shore, all range lights, beacons, and buoys will have individual characteristics formed by flashes and combinations of flashes of light and dark intervals.

EXCAVATION

The total excavation, dry and wet, for the Canal as originally planned, was estimated at 103,795,000 cubic yards, in addition to the excavation by the French companies. Changes in the plan of the Canal, made subsequently by order of the President, increased the amount to 174,666,594 cubic yards. Of this amount, 89,794,493 cubic yards were to be taken from the Central Division, which includes the Culebra Cut. In July, 1910, a further increase of 7,871,172 cubic yards was made, of which 7,330,525 cubic yards were to allow for slides in Culebra Cut, for silting in the Chagres section, and for lowering the bottom of the Canal from 40 to 39 feet above sea level in the Chagres section. These additions increased the estimated total excavation to 182,537,766 cubic yards. In 1911, a further increase of 12,785,613 cubic yards was made, of which 5,257,281 cubic yards was for slides in Culebra Cut, and the remainder for additional excavation and silting in the Atlantic and Pacific entrances, raising the grand total of estimated excavation to 195,323,379 cubic yards. In 1912 a still further increase of 17,180,621 cubic yards was made, of which 3,545,000 cubic yards was for slides in Culebra Cut and the remainder for dredging excavation at Gatun locks, silting in the Atlantic entrance, and for the Balboa terminals, bringing the grand total of estimated excavation to 212,504,000 cubic yards. The Balboa terminals embrace 7,371,000 cubic yards of wet excavation and 1,423,000 cubic yards of dry excavation for the basin and docks. Deducting these amounts, the total for Canal excavation proper, according to the estimate of 1912, is about 203,710,000 cubic yards, or nearly double the amount of the original estimate made in the minority report of the International Board of Consulting Engineers in 1906. The points of deepest excavation are in Culebra

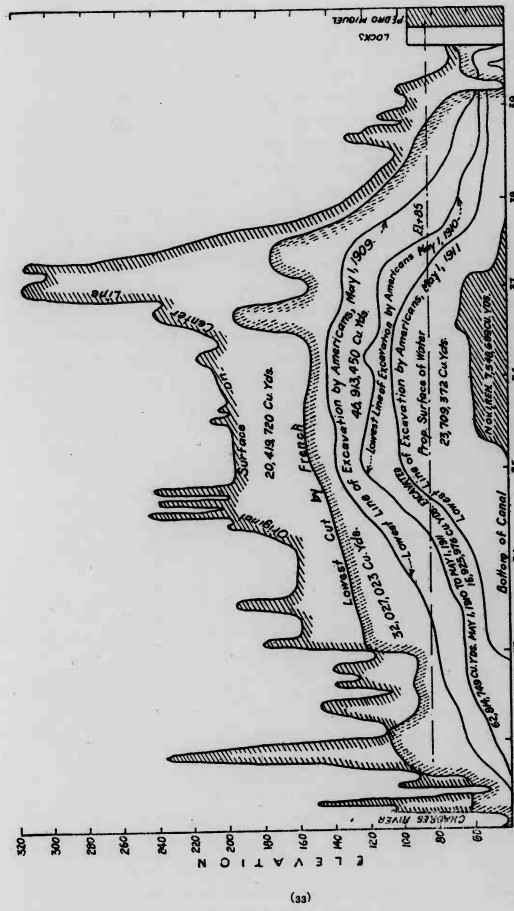


PLATE N

PROFILE OF CULEBRA CUT FROM DIKE AT GAMBOA TO PEDRO MIGUEL LOCKS

Cut, 495 feet above the bottom of the Canal at Gold Hill, and 364 feet above at Contractor's Hill opposite. The widest part of the Cut is opposite the town of Culebra, where owing to the action of slides on both banks, the top width is about half a mile. (Plate O). Active excavation work on a large scale did not begin until 1907, when 15,765,290 cubic yards were removed. In 1908, over 37,000,000 cubic yards were removed, and in 1909, over 35,000,000 making a total for the two years of over 72,000,000 yards, or a monthly average for those two years of 3,000,000 cubic yards. In 1910, over 31,000,000 cubic yards were removed, the monthly average exceeding 2,600,000 cubic yards. The total for these three years was over one half of the entire excavation for the Canal. Records of all excavation to January 1, 1913, are appended. On that date there remained to be excavated in the Cut 5,351,419 cubic yards, and in the entire Canal proper 23,426,713 cubic yards:

By French Companies		78,146,960
French excavation useful to present Canal		29,908,000
By Americans:		
Dry excavation	116,428,685	
Dredges	71,851,627	
Total		188,280,312
May 4 to December 31, 1904	243,472	
January 1 to December 31, 1905	1,799,227	
January 1 to December 31, 1906	4,948,497	
January 1 to December 31, 1907	15,765,290	
January 1 to December 31, 1908	37,116,735	
January 1 to December 31, 1909	35,096,166	
January 1 to December 31, 1910	31,437,677	
January 1 to December 31, 1911	31,603,899	
January 1 to December 31, 1912	30,269,349	

TOTALS BY DIVISIONS AND AMOUNT TO BE EXCAVATED.

Divisions	Amount excavated	Remaining to be excavated
Atlantic—		
Dry excavation	8,702,997	211,120
Dredges	34,021,280	4,986,380
Central—		
Culebra Cut	88,531,237	5,351,419
All other points	12,384.655	150,000
Pacific—		
Dry excavation	6,998,035	3,312,704
Dredges	37,642,108	10,212,203
Grand total	188,280,312	24,223,826

SLIDES AND BREAKS

There have been in all 26 slides and breaks in Culebra Cut; 17 covered areas varying from 1 to 75 acres and 9 covered areas of less than 1 acre each, mak-

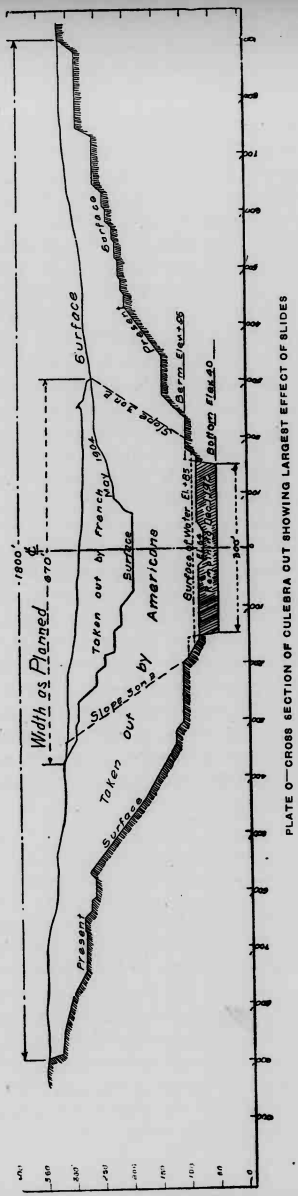


PLATE O—CROSS SECTION OF CULEBRA CUT SHOWING LARGEST EFFECT OF SLIDES

ing in all a total of 225 acres. One variety of slide is caused by the slipping of the top layer of clay and earth on a smooth sloping surface of a harder material. The largest slide of this character is that known as Cucaracha on the east bank of the Canal just south of Gold Hill. This gave the first French company trouble during the final years of its operations. It first gave the Americans trouble in 1905, and between that date and July 1, 1912, nearly 3,000,000 cubic yards of material were removed from the Canal because of it. It broke nearly 1 900 feet back from the axis of the Canal and covers an area of 47 acres. Another variety of slide, properly called break, is due to the steepness of the slopes and the great pressure of the superincumbent material upon the underlying layers of softer material. The largest slide or break of this type is on the west side of the Cut at Culebra just north of Contractor's Hill and covers an area of 75 acres. Over 7,000,000 cubic yards of material have been removed from this slide and it is thought that by the time the Canal shall have been completed something like 10,000,000 cubic yards will have been taken out. On the east side of the Cut a similar slide covers an area of about 50 acres, breaking back about 1,300 feet from the center of the Canal. About a half million cubic yards have been taken out of this slide and more remains to be removed. It is estimated that the total amount of material removed from the Canal because of the slides will aggregate between 21,000,000 and 22,000,000 cubic yards.

DRILLING AND BLASTING

Most of the material excavated in Culebra Cut has consisted of rock varying from very soft, which readily disintegates on exposure to the atmosphere, to very dense rock of great hardness. It has been necessary before excavating this material to drill and blast it. Two kinds of drills have been used—tripod and well—both obtaining their power from a 10-inch compressed air main on the west bank of the Cut which is supplied by three batteries of air compressors placed at equal distances along the 9 miles of the Cut. The usual

depth of drill holes has been about 27 feet, three feet deeper than the steamshovels have excavated. The drill holes, placed about 14 feet apart, are loaded with 45 per cent potassium nitrate dynamite in quantities depending upon the character of the rock, and are connected in parallel and fired by means of a current from an electric light plant. The maximum number of drills in use at any one time in Culebra Cut was 377, of which 221 were tripod and 156 well. With these over 90 miles of holes have been drilled in a single month. A pound of dynamite has been used to about every $2\frac{1}{4}$ cubic yards of material blasted, and the quantity used in Culebra Cut during several years has averaged about 6,000,000 pounds a year.

CAPACITY OF STEAMSHOVELS AND DIRT TRAINS

There are several classes of steamshovels engaged in excavating work, equipped with dippers ranging in capacity from $1\frac{3}{4}$ cubic yards to 5 cubic yards, and a trenching shovel, which has a dipper with a capacity of $\frac{3}{4}$ of a cubic yard. In Culebra Cut excavation the 5-yard dippers have been used almost entirely.

Each cubic yard, place measurement, of average rock weighs about 3,900 pounds; of earth, about 3,000 pounds; of "the run of the Cut," about 3,600 pounds, and is said to represent about a two-horse cart load. Consequently, a five cubic yard dipper, when full, carries 8.7 tons of rock, 6.7 tons of earth, and 8.03 tons of "the run of the Cut."

Three classes of cars are used in hauling spoil—flat cars with one high side, which are unloaded by plows weighing from 14 to 16 tons, operated by a cable upon a winding drum, and two kinds of dump cars, one large and one small. The capacity of the flat cars is 19 cubic yards; that of the large dump cars 17 cubic yards, and that of the small dump cars, 10 cubic yards. The flat car train is ordinarily composed of 20 cars in hauling from the cut at Pedro Miguel, and 21 cars in hauling from the cut at Matachin. The large dump train is composed of 27 cars, and the small dump train of 35 cars.

The average load of a train of flat cars, in hauling the mixed material known as "the run of the Cut," is 610.7 tons (based on a 20-car train); of a train of large dump cars, 737.68 tons, and of a train of small dumps, 562.5 tons.

The average time consumed in unloading a train of flat cars is from 7 to 15 minutes; in unloading a train of large dump cars, 15 to 40 minutes; and in unloading a train of small dump cars, 6 to 56 minutes. The large dump cars are operated by compressed air power furnished by the air pump of the locomotive, while the small dump cars are operated by hand.

The record day's work for one steamshovel was that of March 22, 1910, 4,823 cubic yards of rock (place measurement), or 8,395 tons. The highest daily record in the Central Division was on March 11, 1911, when 51 steam shovels and 2 cranes equipped with orange peel buckets excavated an aggregate of 79,484 cubic yards, or 127,742 tons. During this day, 333 loaded trains and as many empty trains were run to and from the dumping grounds.

The greatest number of shovels in use at one time in the Cut was 43, and the greatest monthly excavation in any single month, in the Cut, was obtained in March, 1911, when 1,728,748 cubic yards of material mostly rock, were excavated.

To handle this amount of material required the services of 115 locomotives and 2,000 cars, giving about 160 loaded trains per day to the dumps, which on the average were about 12 miles distant, the haul one way varying from about one mile to 33 miles. To serve properly the trains and shovels employed in excavation work in the Cut, although it is less than nine miles in length, about 100 miles of track have been required or an average of over nine parallel tracks at all points.

BREAKWATERS

Breakwaters are under construction at the Atlantic and Pacific entrances of the Canal. That in Limon Bay or Colon harbor, extends into the bay from Toro Point at an angle of 42° and 53′ northward

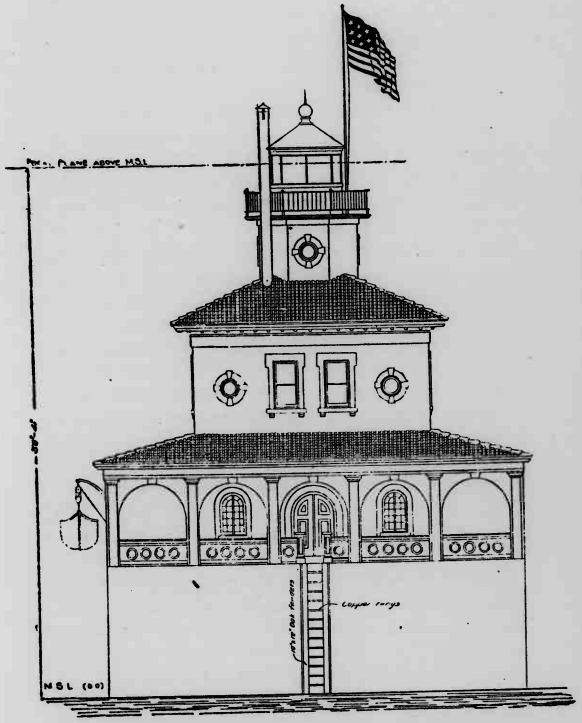


PLATE P—WEST BREAKWATER LIGHTHOUSE—58′ 4″ HIGH

from a base line drawn from Toro Point to Colon light, and will be 10,500 feet in length, or 11,700 feet, including the shore connection, with a width at the top of fifteen feet and a height above mean sea level of ten feet. The width at the bottom will depend largely on the depth of water. It will contain approximately 2,840,000 cubic yards of rock, the core being formed of rock quarried on the mainland near Toro Point, armored with hard rock from Porto Bello. Work began on the breakwater in August, 1910, and on December 1, 1912, the trestle and fill were completed to full length, 11,500 feet. On the same date about one-seventh, or 1,643 feet, of the rock armor had been placed. The estimated cost is $5,500,000. A second breakwater has been proposed for Limon Bay, but this part of the project has not been formally acted upon. The purpose of the breakwaters is to convert Limon Bay into a safe anchorage, to protect shipping in the harbor of Colon, and vessels making the north entrance to the Canal, from the violent northers that are likely to prevail from October to January, and to reduce to a minimum the amount of silt that may be washed into the dredged channel.

The breakwater at the Pacific entrance will extend from Balboa to Naos Island, a distance of about 17,000 feet, or a little more than three miles. It will lie from 900 to 2,700 feet east of and for the greater part of the distance nearly parallel to the axis of the Canal prism; will vary from 20 to 40 feet in height above mean sea level, and will be from 50 to 3,000 feet wide at the top. It is estimated that it will contain about 18,000,000 cubic yards of earth and rock, all of which will be brought from Culebra Cut. It is constructed for a two-fold purpose; first, to divert cross currents that would carry soft material from the shallow harbor of Panama into the Canal channel; second, to furnish rail connection between the islands and the mainland. Work was begun on it in May, 1908, and on November 6, 1912, the last piles were driven connecting Naos Island with the mainland. On the same date about one-half mile of trestle remained to be filled.

APPROPRIATIONS.

Payment to the New Panama Canal Company		$40,000,000.00
Payment to Republic of Panama		10,000,000.00
Appropriation, June 28, 1902		10,000,000.00
Appropriation, December 21, 1905		11,000,000.00
Deficiency, February 27, 1906		5,990,786.00
Appropriation, June 30, 1906		25,456,415.08
Appropriation, March 4, 1907		27,161,367.50
Deficiency, February 15, 1908		12,178,900.00
Appropriation, May 27, 1908		29,187,000.00
Deficiency, March 4, 1909		5,458,000.00
Appropriation, March 4, 1909		33,638,000.00
Deficiency, February 25, 1910		76,000.00
Appropriation, June 25, 1910		37,855,000.00
Appropriation, March 4, 1911		45,560,000.00
Appropriation, August, 24, 1912		28,980,000.00
Private Act.	Relief of Elizabeth G. Martin	1,200.00
Private Act.	Relief of Marcellus Troxell	1,500.00
Private Act.	Relief of W. L. Miles	1,704.18
Private Act.	Relief of Chas. A. Caswell	1,056.00
Private Act.	Relief of Alexandro Comba	500.00
Private Act.	Relief of Douglas B. Thompson	1,500.00
Private Act.	Relief of Robert S. Gill	2,520.00
Total		$322,551,448.76
Appropriation for Fortifications, March 4, 1911		3,000,000.00
Appropriation for Fortifications, August 24, 1912		2,806,950.00

CLASSIFIED EXPENDITURES TO NOVEMBER 1, 1912.

Department of Construction and Engineering	$159,411,558.14
Department of Construction of Engin'ring Plant	2,868,362.47
Department of Sanitation	15,319,682.40
Department of Civil Administration	5,961,599.68
Department of Law	30,887.52
Panama Railroad, Second Main Track	1,123,477.93
Panama Railroad, Relocated Line	8,866,392.02
Purchase and Repair of Steamers	2,680,112.01
Zone Water Works and Sewers	5,140,506.45
Zone Roadways	1,579,724.67
Loans to Panama Railroad Company	3,247,332.11
Construction and Repair of Buildings	10,188,813.63
Purchase from New Panama Canal Company	40,000,000.00
Payment to Republic of Panama	10,000,000.00
Miscellaneous	4,207,175.37
Total	$270,625,624.40
Expenditures for Fortifications to Nov. 1, 1912	1,685,315.75

The balances carried in expenditure accounts, which are included in the last item above, for water works, sewers, and pavements in the cities of Panama and Colon amounted altogether to $2,395,358.79. The unexpended balance in the appropriation for sanitation in the cities of Panama and Colon, available for expenditures on water works, sewers, and pavements was $97,465.64, including transfer of appropriations for quarter ended September 30, 1912.

A careful official estimate has been made by the Canal Commission of the value to the Commission at the present time of the franchises, equipment, material, work done, and property of various kinds for which the United States paid the French Canal Company $40,000,000. It places the total value at $42,000,000, divided as follows:

Excavation, useful to the Canal, 29,708,000 cubic yards	$25,389,240.00
Panama Railroad Stock	9,644,320.00
Plant and material, used, and sold for scrap	2,112,063.00
Buildings, used	2,054,203.00
Surveys, plans, maps, and records	2,000,000.00
Land	1,000,000.00
Clearings, roads, etc	100,000.00
Ship channel in Panama Bay, four years' use	500,000.00
Total	$42,799,826.00

CANAL ZONE

The Canal Zone contains about 436 square miles, about 95 of which will be under the waters of the Canal and Gatun and Miraflores Lakes. It begins at a point 3 marine miles from mean low water mark in each ocean, and extends for 5 miles on each side of the center line of the route of the Canal. It includes the group of islands in the Bay of Panama named Perico, Naos, Culebra, and Flamenco. The cities of Panama and Colon are excluded from the Zone, but the United States has the right to enforce sanitary ordinances in those cities, and to maintain public order in them in case the Republic of Panama should not be able, in the judgment of the United States, to do so.

Of the 436 square miles of Zone territory, the United States owns about 363, and 73 are held in private ownership. Under the treaty with Panama, the United States has the right to acquire by purchase, or by the exercise of the right of eminent domain, any lands, buildings, water rights, or other properties necessary and convenient for the construction, maintenance, operation, sanitation, and protection of the Canal, and it can, therefore, at any time acquire the lands

within the Zone boundries which are owned by private persons. The United States will also control the area to be covered by Gatun Lake which extends beyond the lines of the Canal Zone.

The population of the Canal Zone, official census, is 62,810; of Panama City, 35,368; of Colon, 17,749.

CANAL FORCE, QUARTERS AND SUPPLIES

The Canal force is recruited and housed by the Quartermaster's Department which has two general branches, labor and quarters, and material and supplies. Through the labor and quarters branch there have been brought to the Isthmus 44,394 laborers, of whom 11,797 came from Europe, 19,448 from Barbados, the balance from other islands in the West Indies and from Colombia. No recruiting is required at present, the supply of labor on the Isthmus being ample.

On December 1, 1912, the total force of the Isthmian Canal Commission and Panama Railroad Company, actually at work, was divided as follows:

	Gold	Silver	Total
Isthmian Canal Commission	4,475	26,199	30,594
Panama Railroad Company	630	4,256	4,886
Panama Railroad Commissary	257	923	1,180
Totals	5,362	31,298	36,660

In addition to the above there were in the employ of contractors on the Isthmus, 454 gold and 3,045 silver employes, a total of 3,499.

The gold force is made up of the officials, clerical force, construction men, and skilled artisans of the Isthmian Canal Commission and Panama Railroad Company. Practically all of them are Americans. The silver force represents the unskilled laborers of the Commission and the Panama Railroad Company. Of these, about 4,500 are Europeans, mainly, Spaniards, with a few Italians and other races. The remainder, about 25,000, are West Indians, about 5,000 of whom are employed as artisans receiving 16, 20, 25, 32, and 44 cents an hour and 7,000 on a monthly basis. The standard rate for the West Indian

laborer is 10 cents an hour, but a few of these doing work of an exceptional character are paid 16 and 20 cents. The larger part of the Spaniards are paid 20 cents an hour, and the rest 16 cents an hour.

The material and supply branch carries in eight general storehouses a stock of supplies for the Commission and Panama Railroad valued approximately at $4,500,000. About $12,000,000 worth of supplies are purchased annually, requiring the discharge of one steamer each day.

FOOD, CLOTHING, AND OTHER NECESSARIES

The Canal and Panama Railroad forces are supplied with food, clothing and other necessaries through the Subsistence Department, which is divided into two branches—Commissary and Hotel. It does a business of about $7,500,000 per annum. The business done by the Commissary Department amounts to about $6,000,000 per annum, and that done by the hotel branch to about $1,500,000 per annum.

The Commissary system consists of 22 general stores in as many Canal Zone villages and camps along the relocated line of the Panama Railroad. It is estimated that with employes and their dependents, there are about 65,000 people supplied daily with food, clothing and other necessaries. In addition to the retail stores, the following plants are operated at Cristobal: Cold storage, ice making, bakery, coffee roasting, ice cream, laundry and packing department.

A supply train of 21 cars leaves Cristobal every morning at 4 a. m. It is composed of refrigerator cars containing ice, meats, and other perishable articles, and ten containing other supplies. These are delivered at the stations along the line and distributed to the houses of employes by the Quartermaster's Department.

The hotel branch maintains the Hotel Tivoli at Ancon, and also 18 hotels along the line for white gold employees at which meals are served for thirty cents each. At these 18 hotels there are served monthly about 200,000 meals. There are 17 messes for European laborers, who pay 40 cents per ration

of three meals. There are served at these messes about 200,000 meals per month. There are also operated for the West Indian laborers 16 kitchens, at which they are served a ration of three meals for 27 cents per ration. There are about 100,000 meals served monthly at these kitchens. The supplies for one month for the line hotels, messes and kitchens costs about $85,000; labor and other expenses about $16,500. The monthly receipts, exclusive of the revenue from the Hotel Tivoli, amount to about $105,000.

PERMANENT CANAL STRUCTURES

HEADQUARTERS AND OTHER BUILDINGS

The permanent administration and Canal headquarters building will be on a knoll west of Ancon quarry where it will overlook both the terminal piers and the Canal entrance. It is to have 75,000 square feet of floor space and is to cost not more than $375,000, including $25,000 for that part assigned to permanent records. The quarters for employes attached to the administration building will be erected in the general area adjacent to and northeast of it, and employes connected with the shops, docks, and other terminal facilities at Balboa will be housed in quarters erected in the area surrounding the slope of Sosa Hill and on the fill adjoining the Ancon–Balboa highway. There will be a permanent settlement at Pedro Miguel for employes of the Pacific locks, and one at Gatun for employes of the Atlantic locks. The settlement at Cristobal will be maintained, and possibly the settlement at Ancon. No necessity is apparent for any other than the above five settlements, except for the military forces which may be stationed on the Isthmus.

PIERS

The piers for commercial use at Balboa will be built at right angles to the axis of the Canal, with their ends about 2,650 feet from the center line of the Canal channel. They will be about 1,000 feet long, and 200 feet wide, with 300-foot slips between, and with land-

ings for small boats at the head of each slip for the full width between piers. The construction of one pier only will be undertaken at first. The old French steel wharf, about 1,000 feet long, will be retained for some time in the future, for commercial purposes.

Two wharves and one pier are under construction at Cristobal, behind a mole and breakwater, built out from shore toward the Canal channel, and paralleling the boundary line between Canal Zone and Panamanian waters. Primarily, these docks are to meet the commercial requirements of the Panama railroad, but should there be enough traffic after the Canal is completed to justify it, four other piers, each about 1,000 feet long, and 209 feet wide, with 300-foot slips between will be constructed.

DRY DOCKS

The main drydock will be situated at Balboa, and will be capable of accommodating any vessel that can pass through the Canal locks. It will have a usable length of 1,000 feet, a depth over the keel blocks of 35 feet at mean sealevel, and an entrance width of 110 feet. The entrance will be closed by miter gates, similar to those used in the locks. The drydock will have a rock foundation, and its sides will be lined with concrete. Its equipment will include a 40-ton locomotive crane, with a travel on both sides.

For vessels of smaller type, an auxiliary drydock will be built at Balboa, in lieu of the marine railways originally contemplated. It will have a usable length of 350 feet, a width at entrance of 71 feet, and a depth over the keel blocks of 13½ feet at mean sealevel. It will be provided with a floating caisson. The 40-ton locomotive crane on the main drydock will be utilized for this dock also. The work of providing space for these drydocks, as well as for the new shops, is now under way, and requires the excavation of about 300,000 cubic yards of material from the northwest face of Sosa Hill. The excavated material is used in filling the site for the shops and terminal yard.

On the Atlantic side it is proposed to retain the old French drydock at Mount Hope, which has a usable length of 300 feet, a width at entrance of 50 feet, and a depth over the sill of 13 feet at mean sea level. It

was the opinion of the board in charge of the dock projects, that the commerical requirements in sight would not warrant the construction of a dry dock at Cristobal capable of accommodating large vessels, in view of the building of a drydock at Balboa, to which any large vessel on the Atlantic side could be taken and returned, in case it was found necessary to dock it for repairs.

COALING PLANTS

The plans contemplate furnishing vessels with fuel, fresh water, and supplies of all kinds. The main coaling plant will be situated on the north end of the island, opposite dock No. 11, Cristobal. It will be capable of handling and storing 200,000 tons of coal, with a possible increase of 50 per cent. One hundred thousand tons of the total normal storage is subaqueous. The plant will have railroad connection with the mainland over a bridge of the bascule type, which will cross the French canal at a point about half a mile south of the Mount Hope drydock. The preliminary work on this plant has been begun by the Panama railroad.

A subsidiary coaling plant will be situated at Balboa, at the outer end of the southeast approach wall of the drydock, having a frontage of 500 feet thereon, adapted for discharging vessels. This plant will be capable of handling and storing 100,000 tons of coal, with a possible increase of 50 per cent. Fifty thousand tons of the total normal storage is subaqueous.

FUEL AND OIL SUPPLY

In addition to coal, facilities will be provided at Cristobal and Balboa for supplying shipping, and the Canal works, with fuel oil. In line with this plan, four steel tanks of 40,000 barrels capacity each, have been contracted for in the United States.

SHOPS

The main repair shops will be built at Balboa, and are designed to maintain the following equipment:

1. Lock, spillway, and power plant machinery. 2. Water and land equipment retained for the maintenance of the Canal. 3. Rolling stock and equip-

ment of the Panama railroad. 4. Mechanical apparatus connected with the coaling plants, fortifications, cold storage plant, wireless stations, etc. 5. The making of repairs, etc., required by commercial vessels, and by private individuals and corporations. 6. The making of such repairs as may be required by vessels of the United States Navy.

In addition to these, a number of subsidiary buildings will be erected. All of the structures will be of permanent construction, with steel frames. The sides and ends will be left open for ventilation and light, protection from sun and rain being afforded by overhanging sheds.

The main metal working shops, including machine, erecting and tool shops, the forge and pipe shop, and the boiler and shipfitters' shop, together with the shed for the storage of steel, will be placed end on between the drydock and repair wharf. The general storehouse, foundry, woodworking shops, subsidiary buildings, and office building, will be erected parallel to the line of the drydock and water front, northeast of the main shops. Two lines of railroad tracks will extend past each end of the main metal working shops, and one track through their center. The main shops will be provided with overhead traveling cranes, the crane runways being extended through each end of the buildings over the railroad tracks. As far as possible, the present machinery will be utilized in the new shops. All of it will be electric driven, including both individual and group drive.

It is proposed to retain the drydock shops, for making repairs on the Atlantic side, until sufficient experience is had to determine the extent and character of repair facilities necessary.

FLOATING EQUIPMENT

For the handling of the lock gate leaves, as well as for other Canal requirements, and commercial and general wrecking purposes, one, or two, powerful floating cranes will be purchased. For handling vessels of the largest size at Cristobal and Balboa, two high power harbor tugs will be provided, and for the transportation of coal, fuel oil, and fresh water alongside of vessels, a sufficient number of bar gesand lighters will

be placed in service. The steel barges, now in use by the Canal Commission, can be used to good advantage, after the necessary modifications have been made, in the barge and lighter service. A tender for passengers and mail will be furnished at each terminus also, provided the business justifies it.

RELOCATED PANAMA RAILROAD

The new, or relocated line of the Panama railroad, is 47.11 miles long, or 739 feet longer than the old line. From Colon to Mindi, 4.17 miles, and from Corozal to Panama, 2.83 miles, the old line is used but the remaining 40 miles are new road. From Mindi to Gatun the railroad runs, in general, parallel to the Canal, and ascends from a few feet above tide water elevation to 95 feet above. At Gatun the road leaves the vicinity of the Canal and turns east along Gatun Ridge to a point about 4½ miles from the center line of the Canal, where it turns southward again and crosses the low Gatun Valley to Monte Lirio, from which point it skirts the east shore of Gatun Lake to the beginning of the Culebra Cut at Bas Obispo. In the Gatun Valley section there are several immense embankments, necessary to place the line above the lake level, which in the 3-mile section, aggregate about 5,000,000 cubic yards. Likewise, near the north end of Culebra Cut, where the line is located so as to furnish waste dumps for spoil from the Canal, there are several very heavy embankments. Originally it was intended to carry the railroad through Culebra Cut on a 40-foot berm along the east side, 10 feet above the water level, but the numerous slides have made this plan impracticable, and a line is now constructed, on a high level around the Cut, known locally as the Gold Hill Line. Leaving the berm of the Canal at Bas Obispo, the Gold Hill Line cuts through a ridge of solid rock, and gradually works into the foot hills, reaching a distance from the center line of the Canal of 2 miles opposite Culebra; thence it runs down the Pedro Miguel Valley to Paraiso, where it is only 800 feet from the center line of the Canal. This section of the line is located on a maximum grade of 1¼ per cent, compensated, and has a

total length of 9⅜ miles. The sharpest curve on the whole line is 7°. From the south end of Culebra Cut at Paraiso, the railroad runs practically parallel with the Canal to Panama, with maximum grade of 0.45 per cent. Where the railroad crosses the Gatun River, near Monte Lirio, a steel girder bridge has been erected, the center span of which will be made into a lift span where the Gatun Lake is formed, to permit access to the upper arm of the lake. The Chagres River at Gamboa is crossed on a steel girder bridge, ¼-mile long, with one 200-foot through truss channel span. Numerous other rivers and small streams are crossed on reinforced concrete culverts. Near Miraflores, a tunnel 736 feet long has been built through a hill. The total cost of the new line has been $8,866,392.02.

EQUIPMENT

CANAL SERVICE.

Steam shovels:		
105-ton, 5 cubic yard dippers	15	
95-ton, 4 and 5 cubic yard dippers	30	
70-ton, 2½ and 3 cubic yard dippers	33	
66-ton, 2½ cubic yard dippers	10	
45-ton, 1¾ cubic yard dippers	11	
26-ton	1	
Trenching shovel, ¾ cubic yard dipper	1	
Total		101
Locomotives:		
American—		
106 tons	100	
105 tons	41	
117 tons	20	
Total		161
French		104
Narrow gage, American, 16 tons		33
Electric		9
Total		307
Drills:		
Mechanical churn, or well	196	
Tripod	357	
Total		553

Cars:		
Flat, used with unloading plows	1,760	
Steel dumps, large	596	
Steel dumps, small	1,207	
Ballast dumps	24	
Steel flats	487	
Narrow gage	209	
Motor	6	
Pay Car	1	
Pay Certificate	1	
Automatic, electric	45	
Decauville	224	
Special, shops	12	
Total		4,572
Spreaders		26
Track shifters		9
Unloaders		30
Pile drivers		14
Dredges:		
French ladder	7	
Dipper	3	
Pipeline	7	
Sea-going suction	2	
Clam shell	1	
Total		20
Cranes		47
Rock breaker		1
Tugs		11
Tow boat		1
House boats		3
Clapets		12
Pile driver, floating		3
Crane boat		1
Barges, lighters and scows		72
Launches		29
Drill boats		2
Floating derricks		2

PANAMA RAILROAD.

Locomotives:		
Road, (12 oil burners)	36	
Switch	26	
Total		62

Cars:		
Coaches	57	
Freight	1,434	
Total		1,491
Cranes:		
Locomotive	2	
Wrecking	2	
Total		4
Piledrivers:		
Track	1	
Floating	1	
Total		2
Tugboat		1
Lighters:		
Coal, all steel	5	
Cargo, steel and iron	8	
Total		13
Motor boats		2
Steam ditcher		1

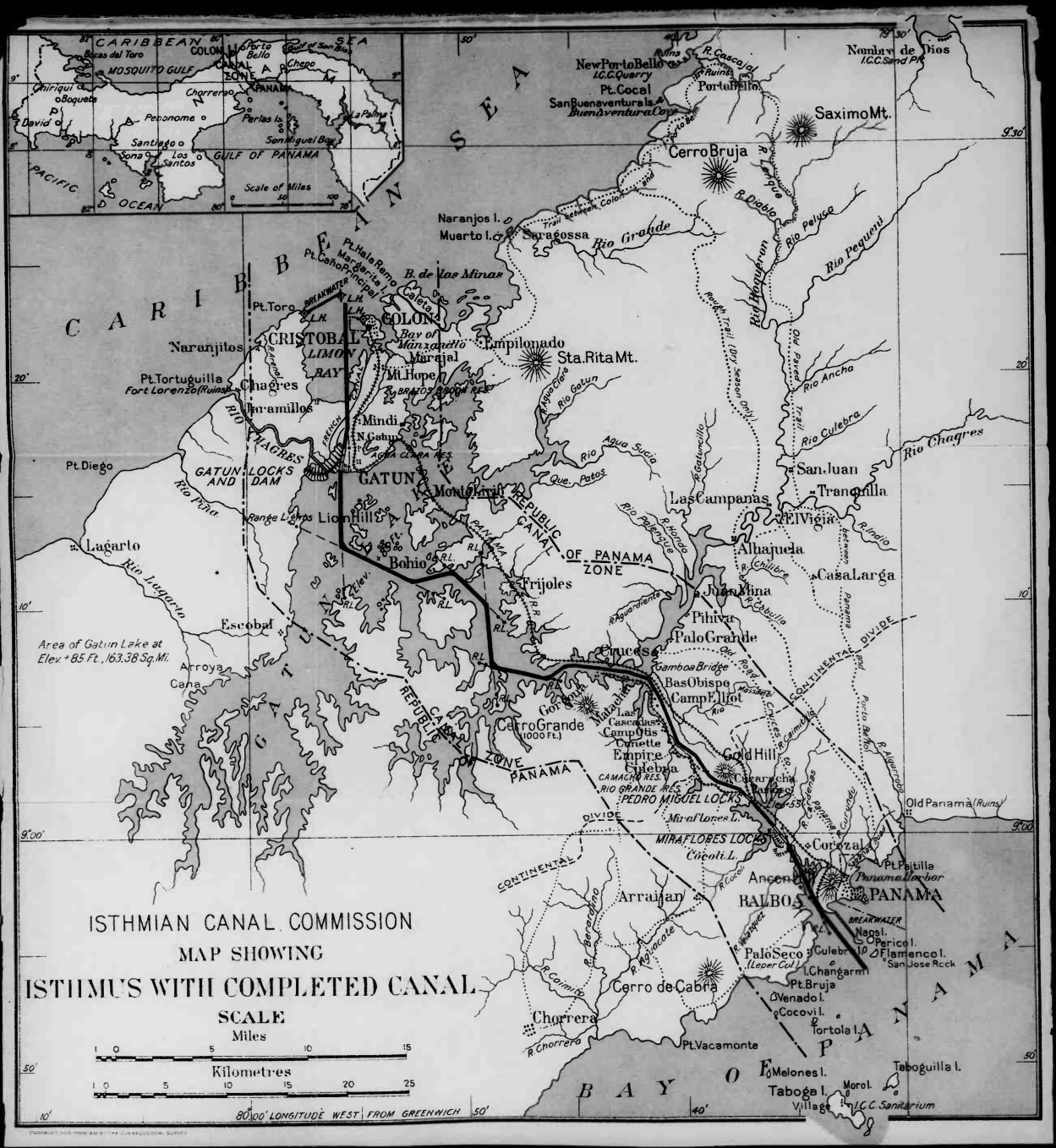
DISTANCES IN NAUTICAL MILES

SAVED FROM NEW YORK VIA THE PANAMA CANAL ON TRADE ROUTES

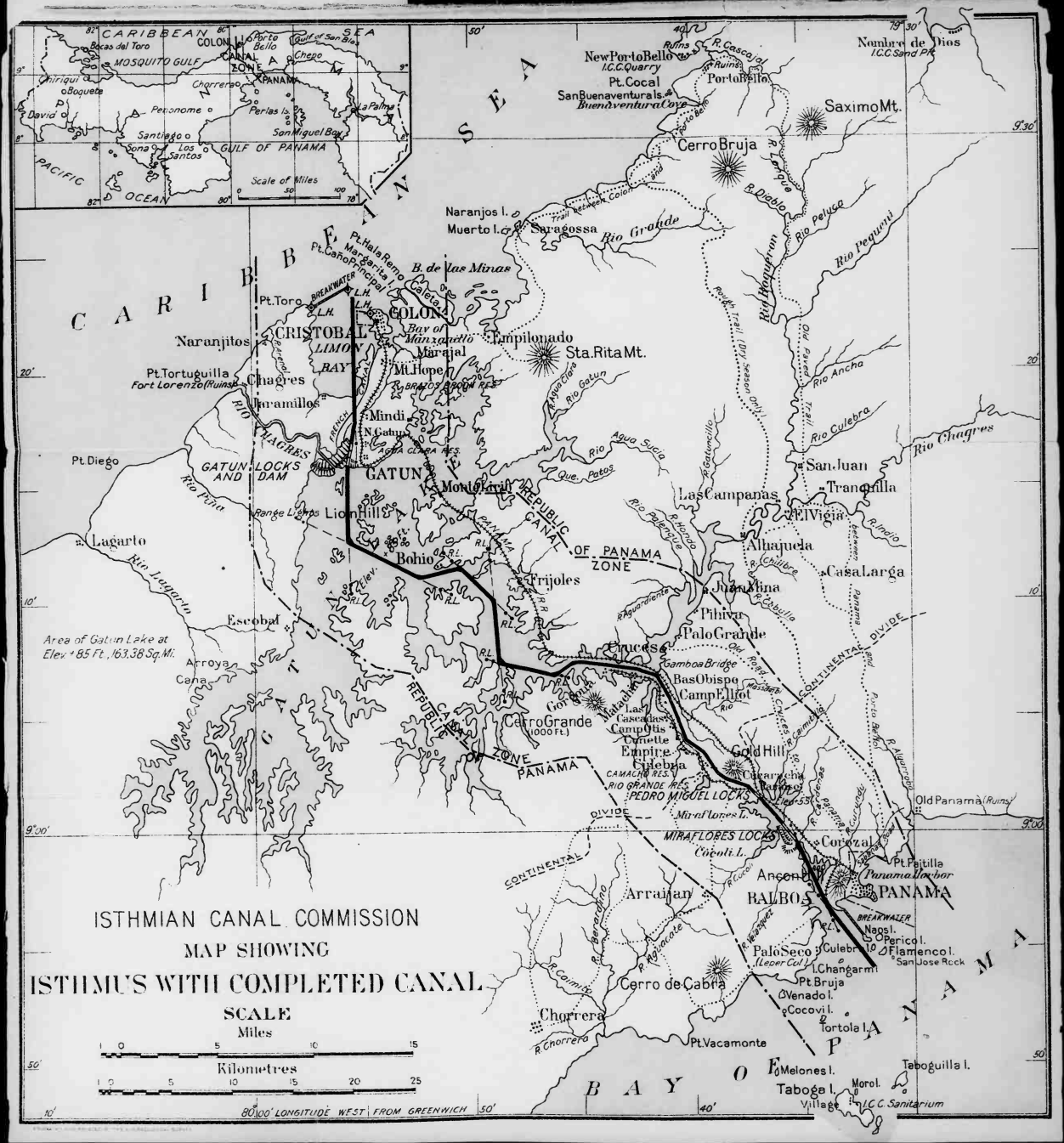
San Francisco:	
Magellan	13,135
Panama	5,262
Saved	7,873
Guayaquil:	
Magellan	10,215
Panama	2,810
Saved	7,405
Callao:	
Magellan	9,613
Panama	3,363
Saved	6,250

Iquique:	
Megellan	9,143
Panama	4,004
Saved	5,139
Valparaiso:	
Magellan	8,380
Panama	4,633
Saved	3,747
Honolulu:	
Magellan	13,312
Panama	6,700
Saved	6,612
Manila:	
Suez	11,589
*Panama	11,548
Saved	41
Yokohama:	
Suez	13,079
*Panama	9,798
Saved	3,281
Hongkong:	
Suez	11,628
*Panama	11,383
Saved	245
Melbourne:	
Magellan	12,852
Panama	10,030
Saved	2,822

*Via San Francisco and the Great Circle.


CARIBBEAN SEA
COLON
Porto Bello
Gulf of San Blas
Bocas del Toro
MOSQUITO GULF
CANAL ZONE
Chepo
PANAMA
Chiriqui
Boquete
Chorrera
David
Penonome
Perlas Is.
La Palma
Santiago
San Miguel Bay
Sona
Los Santos
GULF OF PANAMA
PACIFIC OCEAN
Scale of Miles
CARIBBEAN SEA
New Porto Bello
I.C.C. Quarry
Pt. Cocal
San Buenaventura Is.
Buenaventura Cays
Ruins
R. Cascajal
Portobello
Nombre de Dios
I.C.C. Sand Pit
Saximo Mt.
Cerro Bruja
R. Diablo
R. Lajas
Naranjos I.
Muerto I.
Saragossa
Trail between Colon and Portobello
Rio Grande
Rio Peluca
Rio Peguni
Rio Boquerum
Pt. Hale Reno
Margarita
Pt. Canoe Principal
B. de las Minas
Caleta
BREAKWATER
L.H.
Pt. Toro
COLON
CRISTOBAL
LIMON BAY
Bay of Manzanillo
Naranjitos
Marajal
Empilonado
Sta. Rita Mt.
Mt. Hope
Old Panama R.
Rio Gatun
Agua Clara
Pt. Tortuguilla
Fort Lorenzo (Ruins)
Chagres
Jaramillos
Mindi
N. Gatun
Agua Clara Res.
Rio Chagres
Pt. Diego
GATUN LOCKS AND DAM
GATUN
Monte Lirio
Rio Agua Sucia
Que. Patos
Rio Caimito
Las Campanas
El Vigia
San Juan
Tranquilla
Rio Ancha
Rio Culebra
Rio Chagres
Rio Piña
Range Lights
Lion Hill
REPUBLIC OF PANAMA
CANAL ZONE
Lagarto
Rio Lagarto
Bohio
Trijoles
Alhajuela
Casa Larga
Juan Mina
Pihiva
Palo Grande
Escobal
Area of Gatun Lake at Elev. +85 Ft., 163.38 Sq. Mi.
Arroyo
Cana
Cruces
Gamboa Bridge
Bas Obispo
Camp Elliot
Las Cascadas
Camp Otis
Culebra
Empire
Gold Hill
Cerro Grande (1000 Ft.)
Gorgona
Matachin
Obispo
Rio Chagres
Rio Trinidad
Rio Mamei
Rio Caimito
Rio Pedro Miguel
Rio Curundu
Rio Agua Salud
Rio Paraiso
Rio Obispo
Rio Mindi
Rio Gigante
Rio Chilibre
Rio Cabuya
Rio Indio
Rio Alhajuela
Rio Aguardiente
Rio Palenque
Rio Alonso
Rio Caburicillo
Rio Que. Patos
Rio Agua Sucia
Rio Gatun
Rio Boqueron
Rio Peluca
Rio Pequeni
Rio Ancha
Rio Culebra
Rio Chagres
Rio Indio
Rio Alhajuela
Rio Chilibre
Rio Cabuya

INTENTIONAL SECOND EXPOSURE



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